NWC TP 6869

EXECUTIVE SUMMARY

RESOLVE Project Final Report

Visibility Conditions and Causes of Visibility Degradation In the Mojave Desert of California

by

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FOREWORD

This is an Executive Summary for the RESOLVE (Research On Operations Limiting Visual Extinction) Project Final Report (NWC TP 6869) that documents air quality studies in the Mojave Desert of California. TP 6869 was initiated and authorized by the Joint Policy Planning Board (JPPB) of the R-2508 Restricted Airspace. RESOLVE is part of a Department of Defense (DOD) program to protect flight and weapons test operations in the R-2508 airspace from adverse impacts caused by degraded visibility.

The RESOLVE study was carried out in three overlapping phases: the design and planning phase from 1983 to mid-1984; the data collection phase from August 1983 through August 1985, with various special field experiments carried out intermittently during 1984 through 1986; and midcourse, on-line data analysis begun in late 1984 and completed in late 1985.

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(U) The Department of Defense has been conducting an extensive air-quality study called RESOLVE (Research On Operations Limiting Visual Extinction). The RESOLVE study is part of a DOD program to protect flight and test operations in the Mojave Desert of California from adverse impacts caused by degraded visibility. Historically, the Mojave Desert in Southern California has represented an ideal region for test and training operations because of excellent visibility, dependably good weather, and large areas of unused land and airspace. Since the 1940s a decrease in visibility in the airspace has been occurring and DOD is concerned about potential adverse effects on operations from further declines in visibility. Highlighted in this study are the major conclusions that pertain directly to the two RESOLVE objectives: documenting baseline visibility conditions in the study region and characterizing the causes and major source areas of visibility degradation.

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INTRODUCTION

For several years, the Department of Defense (DOD) has been conducting an extensive air-quality study in the Mojave Desert of California. This study, called RESOLVE (Research On Operations Limiting Visual Extinction), is part of a DOD program to protect military flight and test operations in the desert from adverse impacts caused by degraded visibility. The purpose of the RESOLVE study is to provide a fundamental understanding of visibility conditions and visibility-related atmospheric processes. The two major objectives of RESOLVE are (1) to document baseline visibility conditions in the study region and (2) to characterize the causes and source areas of visibility degradation.

BACKGROUND

Historically, the Mojave Desert in Southern California has represented an ideal region for DOD test and training operations because of excellent visibility, dependably good weather, and large areas of unused land and airspace. Because of these advantages, DOD located a number of major facilities in the region (designated the R-2508 airspace) as shown in Figure 1. The DOD facilities include Edwards and George Air Force Bases, the Naval Weapons Center (NWC), and Fort Irwin Army National Training Center. Together, these facilities employ approximately 37,000 people with a budget of 1.5 billion dollars per year.

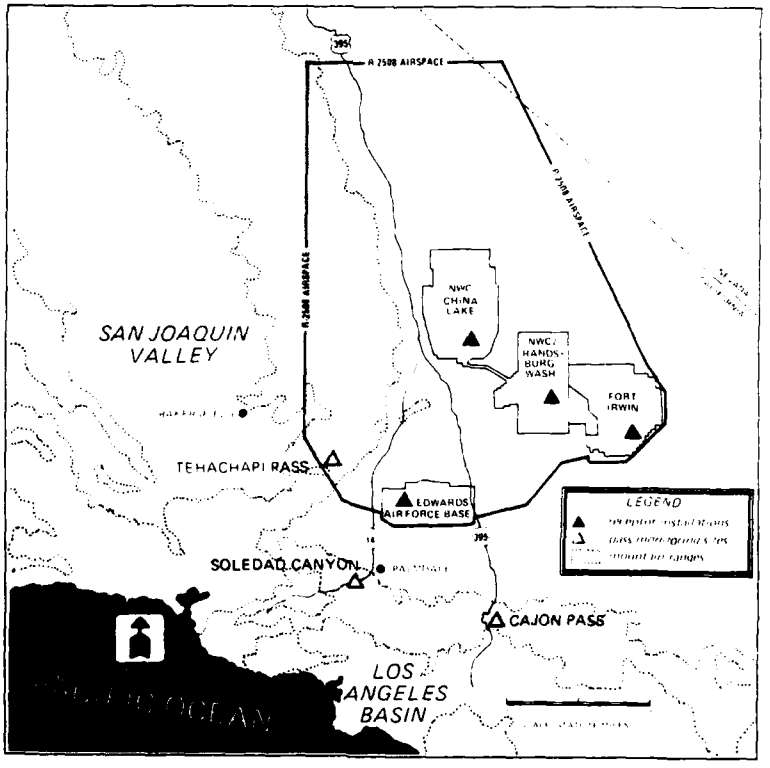


FIGURE 1. RESOLVE Study Area Monitoring Sites.

Since the mid-1940s, when the facilities were established, a decrease in visibility in the R-2508 airspace has been occurring. Now visibility degradation is sometimes severe enough to adversely affect the optical data for certain tests or to force changes in operational procedures. Visibility conditions are still generally adequate for most types of test and training activities conducted at the facilities; however, DOD is concerned about potential adverse effects on current and future operations resulting from further declines in visibility.

The R-2508 Joint Policy Planning Board (JPPB) has formed the DOD Visibility Protection Program (VPP) to develop a management strategy plan to preserve existing atmospheric visibility conditions at the test facilities. As a first step in developing a management strategy, the VPP implemented the RESOLVE field study.

The design, monitoring, and data analysis for RESOLVE was guided by the philosophy to seek the best possible unbiased scientific results. To this end, DOD gathered input and assistance from other interested parties. One area where other organizations gave assistance was in research support. Western Oil and Gas Association (WOGA) and the EPA Environmental Monitoring Systems Laboratory contributed significant resources in support of the RESOLVE study.

The second major area of input was in the review process. The RESOLVE program plan and data analysis plan were widely disseminated among interested parties and publicly presented at workshops. These plans were significantly modified based on resulting comments. Interim products from the study (e.g., data summaries and research papers) were also subject to public and technical scrutiny. This final report has undergone a similar process of review and modification.

MONITORING PROGRAM

The design of the RESOLVE monitoring program was based on the review of prior atmospheric studies in the region and on evaluations of historical data. The program consisted of a routine monitoring network supplemented with 12 special intensive studies. The routine monitoring network included seven stations (shown in Figure 1): three critical receptor sites in the desert (Edwards Air Force Base, NWC, and the Fort Irwin National Training Center), three mountain pass sites leading from upwind air basins to the desert (Tehachapi, Soledad, and Cajon), and another desert site (Randsburg Wash) located on NWC. The monitoring instrumentation provided a detailed characterization of surface meteorology; particle mass, size, and composition; and light extinction. The routine RESOLVE network operated from August 1983 through August 1985. Data recovery for all the monitors was 90 to 95%.

SUMMARY OF MAJOR CONCLUSIONS

We highlight here the major conclusions that pertain directly to the two RESOLVE objectives: documenting baseline visibility conditions in the study region and characterizing the causes and source areas of visibility degradation.

BASELINE VISIBILITY CONDITIONS

Visibility levels at the three RESOLVE receptor sites are fairly uniform. NWC has an average visual range of 89 kilometers (55 miles), Edwards AFB averages about 15% worse than NWC, while Fort Irwin NTC averages about 15% better. Edwards AFB experiences

especially severe worst-case days, while Fort Irwin NTC has especially clear best-case days. The overall visibility conditions for the receptor sites are illustrated in the following table.

Site	Best 10th percentile days, km/mi.	Average extinction, km/mi.	Worst 10th percentile days, km/mi
Edwards AFB	141/87	75/47	44/27
NWC	143/89	89/55	59/37
Fort Irwin NTC	182/113	101/63	60/37
3-Site mean	155/96	88/55	54/33

All three RESOLVE receptor sites experience similar seasonal patterns for visibility. Average visual range is highest in the winter and lowest in the summer. Worst-case conditions are nearly as frequent in the fall as in the summer; and even the winter has a significant share of worst-case days.

The RESOLVE receptor sites show that the desert region has a fair uniformity in terms of day-to-day air quality variations. An examination of visibility values and spatial patterns (shown in Figure 2) indicates that NWC is influenced more by the San Joaquin Valley than by the Los Angeles basin. Edwards AFB and Fort Irwin NTC appear to be significantly affected by both upwind air basins. Edwards AFB has the lowest visibility among the receptor sites because of its closer proximity to the upwind urban source areas.

CAUSES OF VISIBILITY DEGRADATION

Averaged over the three receptor sites, the allocation of visibility degradation by species is as follows: organics 26% ± 9%; sulfates 24% ± 5%; elemental carbon 19% ± 6%; soil dust 18% ± 8%; and nitrates plus NO_2 13% ± 5%. The extinction budget for worst-case days is almost identical to the one for average conditions.

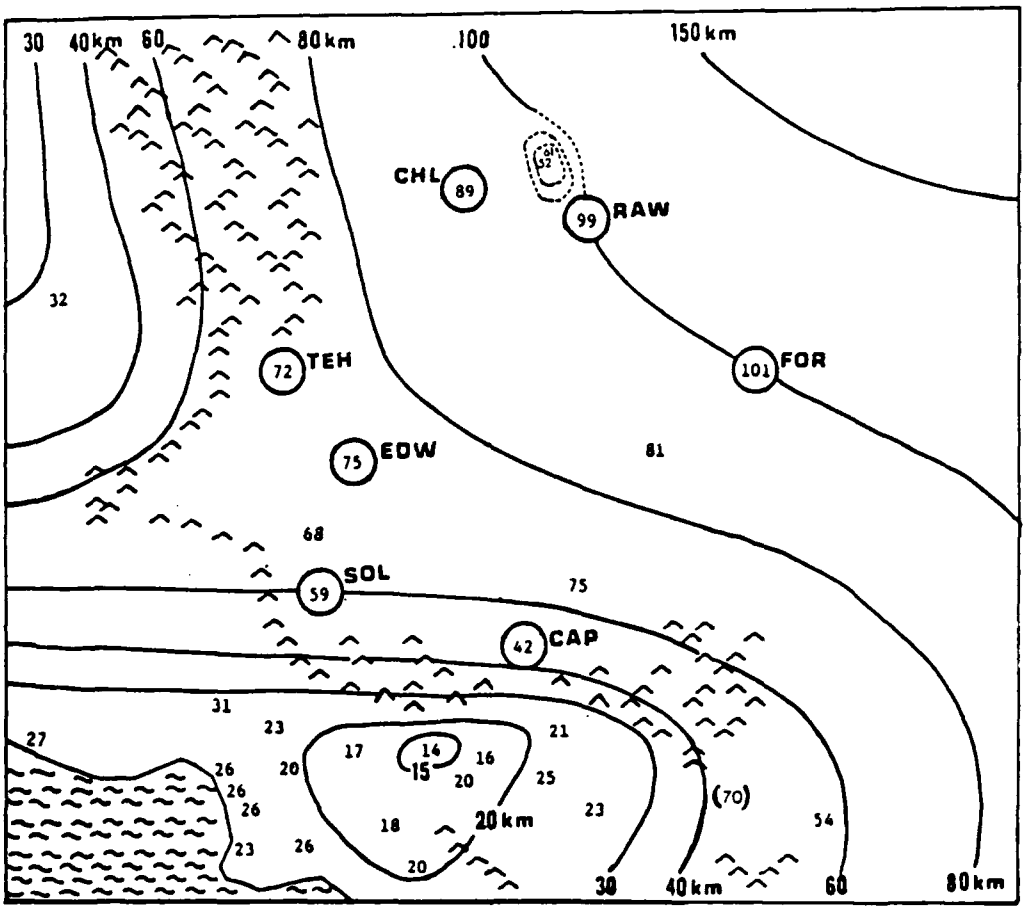
Figure 3 shows the allocation of the relative contribution of visibility degradation among the five major pollutants at Edwards AFB and NWC.

SOURCES OF VISIBILITY DEGRADATION

Results indicate that just five types of atmospheric pollutants are responsible for nearly all visibility degradation in the desert. These five categories of atmospheric pollutants are sulfates (from SO_X emissions), nitrates plus NO_X (from NO_X emissions), elemental carbon, organics, and soil dust (see Figure 4). The first three categories are generally dominated by man-made emissions (80%), while the last two aerosol types (organics and soil dust) arise from a wide variety of both natural and man-made sources.

Various analyses indicate that all of the atmospheric pollutants except soil dust are dominated by man-made sources from upwind air basins.

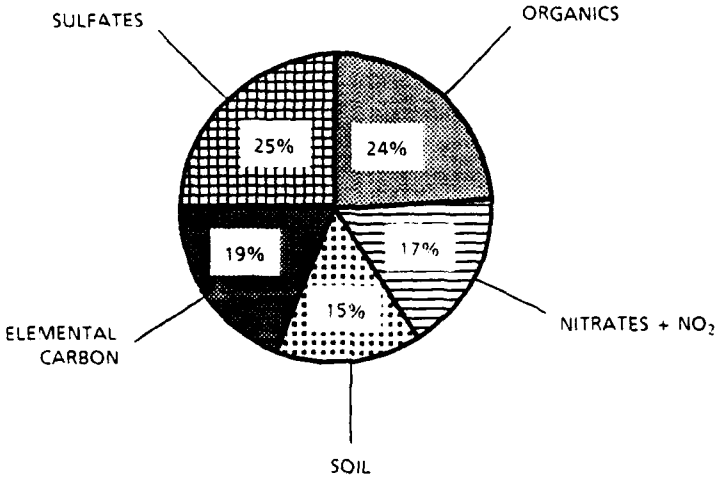
On the average, the single most significant source of visibility degradation in the study region appears to be anthropogenic (man-made) transport from the San Joaquin Valley, accounting for about one-half of visibility extinction. In the northern majority of the study region (NWC), the remainder of visibility extinction comes from natural and local sources. Along the southern edge of the study region, contributions from Los Angeles and natural and local sources are significant. For the worst-case days at Edwards AFB and Fort Irwin NTC, transport from the Los Angeles basin appears to be more important than it is for average contributions.



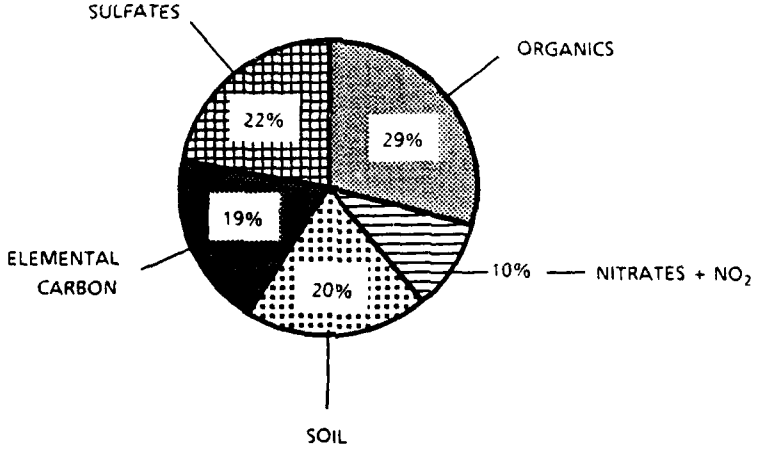
NOTES:

- Circled data points represent RESOLVE monitoring data. The entire 2 years of RESOLVE data were used, with *nephelometer scattering factored to non-Rayleigh extinction using site-specific RESOLVE base-year* relationships and 11 Mm^{-1} added for Rayleigh scatter.
- Smaller print data points are based on particle-scattering data in and near Searles Valley. The data are factored to total extinction using RESOLVE relationships.
- *Other data points are based on median airport data calibrated to RESOLVE data.*
- The dashed lines indicate uncertainty in the isopleths near Searles Valley.
- Isopleths near the border of the map are guided by nephelometer data at Death Valley as well as data from other airports in California and Nevada.
- The Beaumont (Banning Pass) value, shown in parentheses, is inconsistent (higher) than surrounding stations. This inconsistency may be because of the high altitude of that site (790 meters) or because of uncertainties associated with the limited visibility markers at that site.
- The following abbreviations are used in this figure for the stations: Edwards AFB, EDW; NWC, CHL; Fort Irwin NTC, FOR; Soledad Pass, SOL; Cajon Pass, CAP; Tehachapi Pass, TEH; and Randsburg Wash, RAW.

FIGURE 2. Spatial Pattern of Visual Range (for 2% Contrast and Average Extinction Levels) In and Near the RESOLVE Study Area.



Edwards Air Force Base



NWC

FIGURE 3. RESOLVE Extinction Budget.

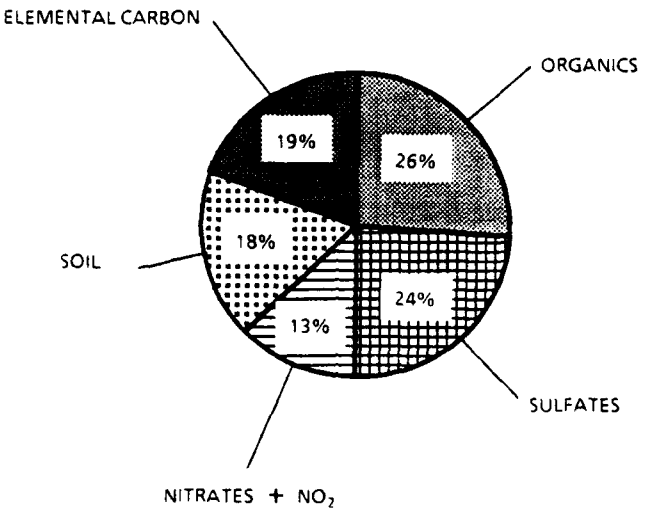


FIGURE 4. Average Concentrations of Atmospheric Species Affecting Visibility.

The RESOLVE analyses concluded that, on the average, approximately three-fourths of visibility degradation was man-made. The other one-fourth was natural. Of that man-made contribution, approximately two-thirds was transported from the San Joaquin Valley and one-third was contributed by Los Angeles and local sources (see Figure 5).

Three individual source categories contribute significantly to man-made extinction in the RESOLVE region: diesel-powered vehicles and equipment, the petroleum industry, and gasoline-powered vehicles. Together, these sources account for about 60% of anthropogenic extinction, with the diesel category alone contributing about one-quarter of man-made extinction.

In Figure 6 we show the breakdown of the man-made emission source categories. Diesel-powered vehicles and equipment account for 26%, the petroleum industry (mostly the San Joaquin Valley) accounts for 18%, and gasoline-powered vehicles (including exhaust and suspended dust) account for 16%. Individual single-source categories account for less than 5% of man-made extinction in the region as a whole; combined they account for 40%.

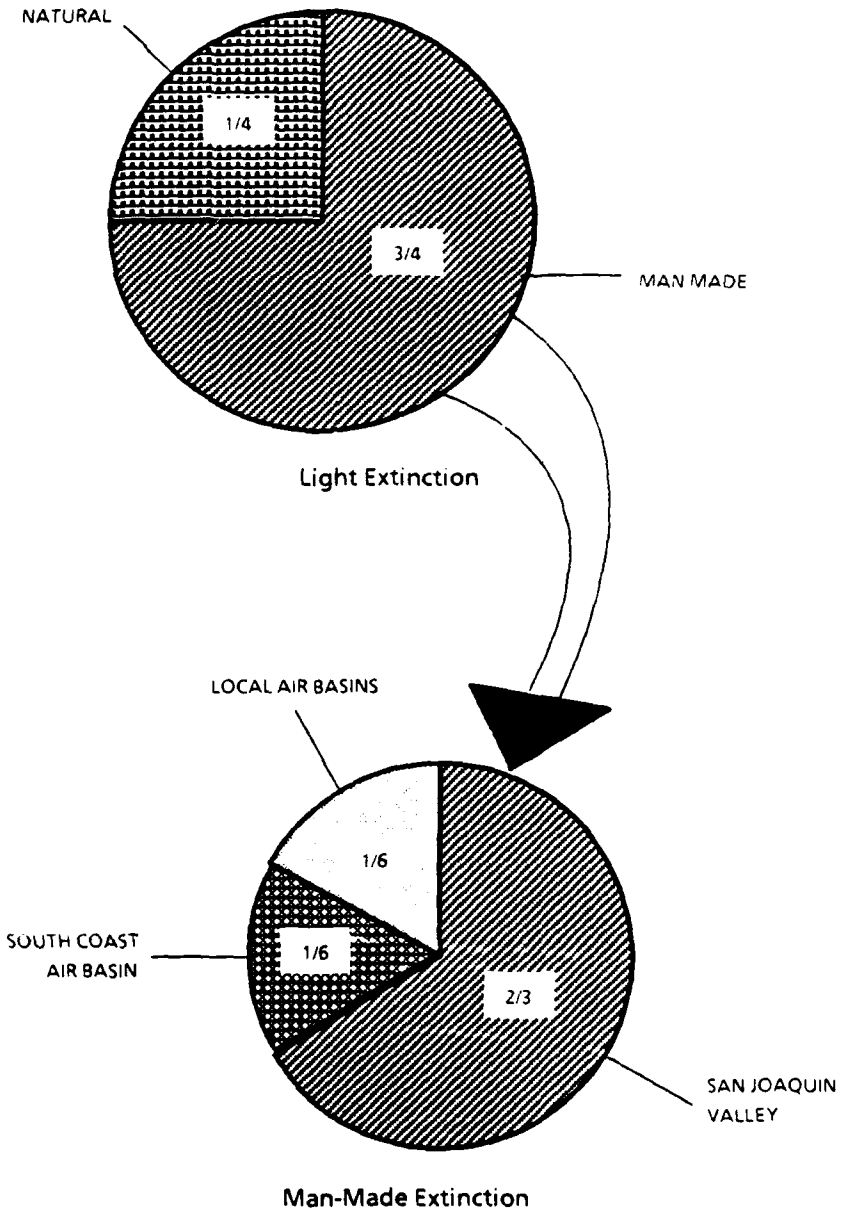
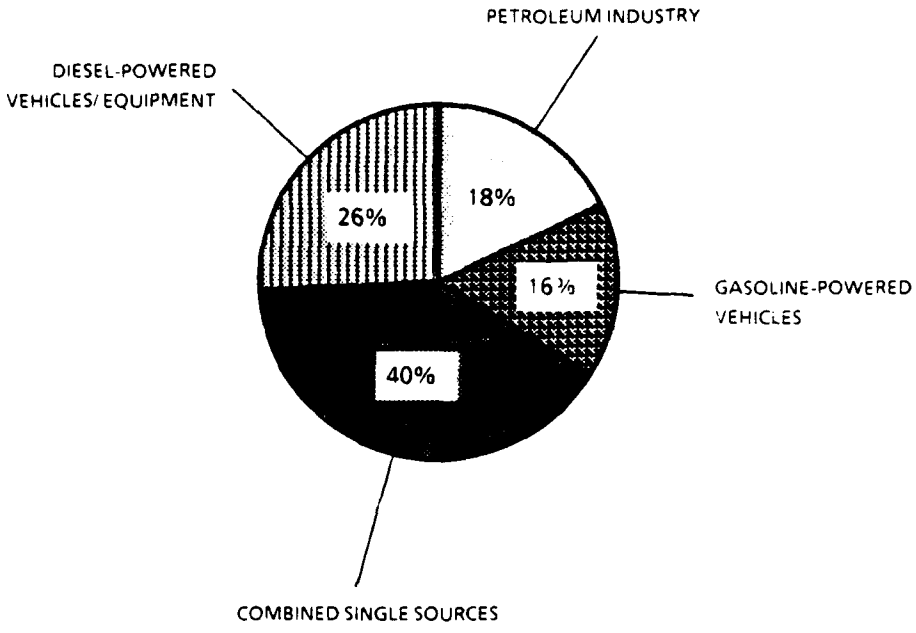


FIGURE 5. Percentage of Man-Made and Natural Light Extinction with Expansion Showing Source Percentage of Man-Made Extinction in the RESOLVE Study Area.



- Emission sources from the petroleum industry are mostly from the San Joaquin Valley.
- Emission sources from gasoline-powered vehicles include exhaust and suspended dust.
- Single sources account for less than 5% but combined single sources account for 40%

FIGURE 6. Man-Made Emission Source Categories.